

SURVEY OF CURRENT STORMWATER DESIGN PRACTICES

Melissa Lilburn

AUTHOR: Water Resources Engineer, ARCADIS Geraghty & Miller, 2849 Paces Ferry Road, Suite 400, Atlanta Georgia 30339

REFERENCES: *Proceedings of the 1999 Georgia Water Resources Conference*, held March 30-31, 1999 at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. This project was part of an EPA funded study to collect information on procedures used by drainage design engineers to design stormwater facilities. Assimilation of information was accomplished through a questionnaire distributed to practicing engineers across the country. The questions asked in this survey pertained to methods of design, consideration of existing conditions, and use of regional site information. The goal of this study was to evaluate the level of technology in common usage and to determine the motivations behind the use of these technologies. The results can be used to develop tools to ensure appropriate application of the various design technologies.

INTRODUCTION

A wide range of drainage design technologies are available to the design engineer. This is logical in that each drainage design is unique, and therefore use of methodologies for one design application may not be appropriate for another. The number of design technologies available, however may impede development of a solid understanding of the basic design methods. In this study, a survey was used to collect information from drainage engineers. Using a survey provided a means to communicate directly with those engineers completing the designs. By doing this, the influences of regulations or public opinion were eliminated and the actual practices used were recorded. Also, these practicing engineers best perceive not only their objectives in design, but also the parameters they consider paramount.

SURVEY DISTRIBUTION AND RESPONSE

An important aspect of a successful survey is adequate distribution to a broad range of participants. Surveys were sent via e-mail and postal mail. E-mail surveys were sent across list servers, including water-on-line, NPSINFO, DIALOG-AGUA, ca-water, SEWER-LIST, water-distrib-systems, hydrology, and a host of others. To eliminate possible bias incurred through surveying only those engineers

utilizing computers and e-mail, the survey was also mailed to more than 350 recipients across the nation.

Response to the survey was satisfactory, with approximately 100 responses received. E-mail responses were not as numerous as expected; only 17 of the 100 surveys received were collected in this manner. The response from the postal mailings was surprising; 21% of surveys received through the mail were returned. A breakdown of survey participants by geographic region is shown in Table 1.

SURVEY QUESTIONS AND RESULTS

Survey Questions

Survey questions were designed to facilitate and encourage a larger number of replies. In all possible cases, choices of answers were provided to make the questions easy to answer and to simplify the analysis of the responses.

Respondent Identification

Initially, the respondent was asked to provide his or her name and position. This information helped to ensure that the individuals responding to the survey were qualified and actually practiced drainage design. Consultants at private engineering firms completed the most surveys. Other respondents were affiliated with water boards and other government entities. Survey participants were classified by job description as shown in Table 2.

Table 1 - Distribution of Survey Respondents

| Geographic Region | % of total |
|-------------------|------------|
| Northeast | 16 |
| Southeast | 20 |
| Mid-West | 38 |
| West | 11 |

Table 2 - Respondent Identification

| Job title | Responses | % of total |
|----------------------------------|-----------|------------|
| Consultant | 45 | 55 |
| Municipal position | 34 | 41 |
| State Dept. of Transportation | 3 | 4 |
| Totals | 82 | 100 |

Design Authority

The first question on the survey inquired as to who established acceptable design methods and levels of service. The two choices provided were "clients" or "regulations". Inferences can be drawn from this information concerning stormwater regulations, such as whether regulations are the driving force in design. It was determined from answers to this question that regulations govern acceptable design methods and levels of service for most projects. Seventy-five percent of those responding indicated that regulations dictated their designs. These regulations were usually established by local or county authorities, indicating a regional focus for this issue. Only 8% of those answering this question indicated that clients dictated the levels of service, while 15.5% stated that both clients and regulations dictated their decisions. A breakdown of design method and level of service decision-making authority is shown in Table 3.

Design Storm Use

Question 2 investigated design storm frequencies used based on various land uses. The land use categories investigated include low-density residential, medium-density residential, high-density residential, strip commercial, shopping centers/malls, downtown commercial, industrial, and institutional. Information provided with respect to this question was difficult to interpret because of the variation in answers, and because fewer participants responded with adequate information. This being the case, the conclusions

Table 3 - Design Authority

| Determining factor | Responses | % of total |
|--------------------|-----------|------------|
| Regulations | 63 | 75 |
| Clients | 8 | 8 |
| Both | 13 | 15 |

are not indicative of the entire group of respondents. Of the quantifiable answers, it appeared that most participants (42.4%) used a 10-year storm for drainage design in all land uses. Several of the engineers using of 10-year storms indicated that most structures were also checked for flooding with respect to the 100-year storm. Ten percent of the respondents indicated use of a 5-year design storm, 8.5% indicated use of a 100-year storm, and 6.8% indicated use of a 25-year storm for all types of land use areas. Most other answers were combinations of storms, based on land use. In these cases, the design storms ranged from 2- to 100-year return intervals, with the smaller storms being used in less densely urbanized areas and larger storms in more urbanized areas. One survey participant mentioned that one storm recurrence was used for drainage design while a shorter duration and, more frequently occurring storm, was used for water quality concerns.

Design Methods

Next, the respondent was asked to describe the design method used most often. The most popular methods were listed as choices, including the Rational Method and Soil Conservation Service (SCS) procedures (Maidment, 1993). The respondent could also indicate any regional method used or additional methods not listed. The method most commonly used to design storm sewers is the Rational Method, with 40.7% of those responding indicating this as the method of choice. Others, 31.4%, used a combination of the Rational and SCS methods. Among those using both methods, the size of the area determined which method was appropriate. The Rational Method was used to design smaller areas, while the SCS procedures were used for larger areas. Fourteen percent of the survey participants indicated that they used only SCS methods, 12.8% used regional methods, and 1.2% used other methods. The regional methods varied from procedures designed with the specific area in mind to others that use only computer design packages. Table 4 provides a summary of these responses.

Computer Model Use

Question 4 inquired about the use of storm drainage models and the percentage of designers currently using computer programs, and also the most popular and commonly used programs. Determining which models are in use also indicates the parameters of concern in design, as different packages use different information in their calculations and models. Eighty-five percent of the respondents to this question stated they use some form of a computer model. The choice of models in use was also broken down, with most designers (24.8%) using the EPA's Stormwater Management Model (SWMM). (EPA, 1988). HEC-1 (US Army Corps of

Engineers, 1991) was the second most popular model, used by 16.8% of those using models. Other computer modeling packages with significant numbers of users were based on TR-55 and TR-20 (SCS, 1986) methods and various Haestad Methods programs. Custom programs (typically designed in-house or for a specific region) were used by 7.9%. A summary of computer program usage specified by respondents is shown in Table 5.

Time of Concentration

Next, the respondent was asked to identify how time of concentration is determined in watersheds. Again, choices were provided for the most common methods.

The three selections were local engineering practice, time of concentration formulas (Kirpich, Izzard, FAA, etc.), and field testing and local measurements (Maidment, 1993). The method used in the computation of time of concentration gives a good indication of how accurate the design predictions can be. Of the 93 individuals responding to this question, time of concentration formulas were by 64.5%. Local engineering practice was used by 29% of the participants. These were mostly rules of thumb used by engineers when dealing with areas having shared characteristics. Only 6.5% used field

testing and local measurements to determine time of concentration. Use of field testing and local measurements provide the most accurate, but most expensive, means for establishing time of concentration. Use of local engineering practice, can be fairly accurate as well, because many of the so-called rules of thumb are based on actual observed conditions.

Failure Criteria

Failure of stormwater systems was covered in the next portion of the survey. A list of occurrences that commonly indicate system failure was provided. For each of these occurrences the respondent was asked to identify the frequency and/or the duration of the particular event necessary for the system to be considered inadequate. The great variety of stormwater drainage systems, not to mention storm frequencies found across the country, caused answers to this question to cover a wide range of situations. The answers were rather vague, and it was difficult to detect a pattern. The most common indication of system failure was manhole covers popping off. Water entering basements and rising above curbs and streets were also widespread indicators. Usually, these situations occurring during less than a 10-year design storm were considered system failures. A low number of participants reported that the occurrence of combined sewer overflows indicated system failure. This is likely a result of the fact that many areas surveyed do not have combined sewer systems. With respect to all the occurrences, and based on the number of responses provided, it appears that designers took these occurrences as evidence of the need for system maintenance and investigated them on a complaint-driven basis.

Stormwater Quality Concerns

Finally, the survey recipients were asked to identify water quality concerns associated with storm runoff. This question was left open-ended in order for a wide range of concerns to be mentioned. Most of the 80 respondents here recognized the most commonly found constituents of stormwater pollution. The most widespread concern was sediment, with 62.5% of the participants mentioning this as a pollutant of concern. Nutrients and metals were the other most common answers, 35% and 33.8%, respectively. Other frequent answers were oil and grease, bacteria, toxics, combined sewer overflows, floatables, and salts. A few survey participants answered the question from a different angle and stated that their main water quality concern with stormwater pollution dealt with permit and discharge limits. Their focus was simply to remain within these regulated limits. A breakdown of this information is shown in Table 6.

Table 4 - Design Method

| Design Method | Responses | % of Total |
|-----------------|-----------|------------|
| Rational method | 35 | 41 |
| NRCS (SCS) | 12 | 14 |
| NRCS & rational | 27 | 31 |
| Regional | 11 | 13 |
| Other | 1 | 1 |

Table 5 - Computer Package Use

| Computer package | Responses | % of total |
|---------------------------------|-----------|------------|
| SWMM | 26 | 24.8 |
| HEC | 17 | 16.8 |
| TR-55 & TR-20 based packages | 13 | 12.9 |
| Custom | 8 | 7.9 |

CONCLUSIONS

Information obtained from this survey has provided a great deal of information about the design of stormwater systems in the United States. Using these data, conclusions can be made on an issue by issue basis about the state of stormwater system design. Information provided by responses to the question on design authority leads to the conclusion that changes in regulations would be necessary to make adjustments to the methods selected by design engineers. Regulations determine the methods used by most engineers, therefore, in order to make significant changes to the method selections, modifications must first be made to the governing regulations.

From the survey results it was determined that decisions with regard to design storm frequency were made on a structure-specific basis rather than by land use classification. Engineers generally use a wide range of storm frequencies depending on whether the structure is a commercial or residential building, a road or a drainage structure.

It has been determined that the predominant design methods are those accepted by regulations with which engineers feel the most comfortable. Given the ease of use and acceptability of the Rational Method, it is by far the method of choice for most engineers. The survey also indicated that engineers were cognizant of the limitations of the method. Designers used alternate methods for drainage areas outside the limitations of the Rational Method. Tools to facilitate or fine-tune the use of the Rational Method would be beneficial. Modifications to methods to better reflect localized conditions would aid in more accurately predicting stormwater runoff.

Water quality concerns identified by the survey respondents were generally uniform. Engineers appear to have an adequate understanding of the parameters of concern. However, very few measures seem to be taken to address this issue. It is in this area that the greatest improvements in storm drainage can be made.

No correlation was made between different regions surveyed and the factors of interest within them. For the purpose of this study, the responses received from each area were examined to determine the applicability of the results. It would be interesting, however, to determine differences or similarities between geographical regions of the country.

LITERATURE CITED

- Environmental Protection Agency, Stormwater Management Model, Version 4, 1989.
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Soil Conservation Service. 1986. Urban Hydrology for Small Watersheds, Technical Release 55.
US Army Corps of Engineers. HEC-1 Flood Hydrograph Package, 1991.

Table 6 - Stormwater Pollutant Concerns

| Constituents | Responses | % of total |
|--------------|-----------|------------|
| Sediment | 50 | 62.5 |
| Nutrients | 28 | 35 |
| Metals | 27 | 33.8 |
| Oils/grease | 24 | 30 |
| Bacteria | 18 | 22.5 |
| Toxics | 14 | 17.5 |
| CSOs | 10 | 12.5 |